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Collembolan communities in winter wheat - clover cropping system on two different soil types

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ABSTRACT. Soil-biological investigations were carried out in the East - Slovak Lowland in 1991 - 1993 at various sites within two soil types, albic luvisol and fluvisol. In this paper we present a synecological study of collembolan communities of two adjacent sites with the same cultivation and cropping system and different soil type.

Gleyic fluvisol with 71.0% clay had 2.1% organic matter and 1400 ind./m² of *Collembola* on an average. Albic fluvisol with 34.0% clay had 1.11% organic matter and an average collembolan abundance of 950 ind./m². At both experimental sites 63 species were found, 51 on luvisol and 41 on fluvisol. Five of dominant species preferred albic luvisol and seven gleyic fluvisol. In spite of uniformity of soil conditions caused by the same cropping system multivariate analysis showed the effect of soil type combined with sampling date on *Collembola*.

INTRODUCTION

In 1989 investigations in arable soils of the south - eastern part of Slovakia were started. In the area of the East-Slovak Lowland and Košice-basin twelve research localities were chosen for long-term studies. The aim of these studies was to estimate the role of soil type in soil-biological activity. Special attention was paid to communities of soil fauna, and especially to *Lumbricidae*, *Oribatida* and *Collembola*.

CURRY (1978) stressed the role of soil type and its related properties, mainly porosity, acidity, organic matter and moisture content in the distribution of soil mesofauna. Several authors investigated various aspects of the effect of soil type on *Collembola* in agroecosystems (ALEJNIKOVA, MARTYNOVA 1966, ANDRÉN, LAGERLÖF 1983, RICKERL, CURL, TOUCHTON 1989, RÖSKE 1989, FROMM et al. 1993). Organic matter content in a given type of soil seems to be the most important factor for these animals, although some contradictory results were reported (RÖSKE 1989).

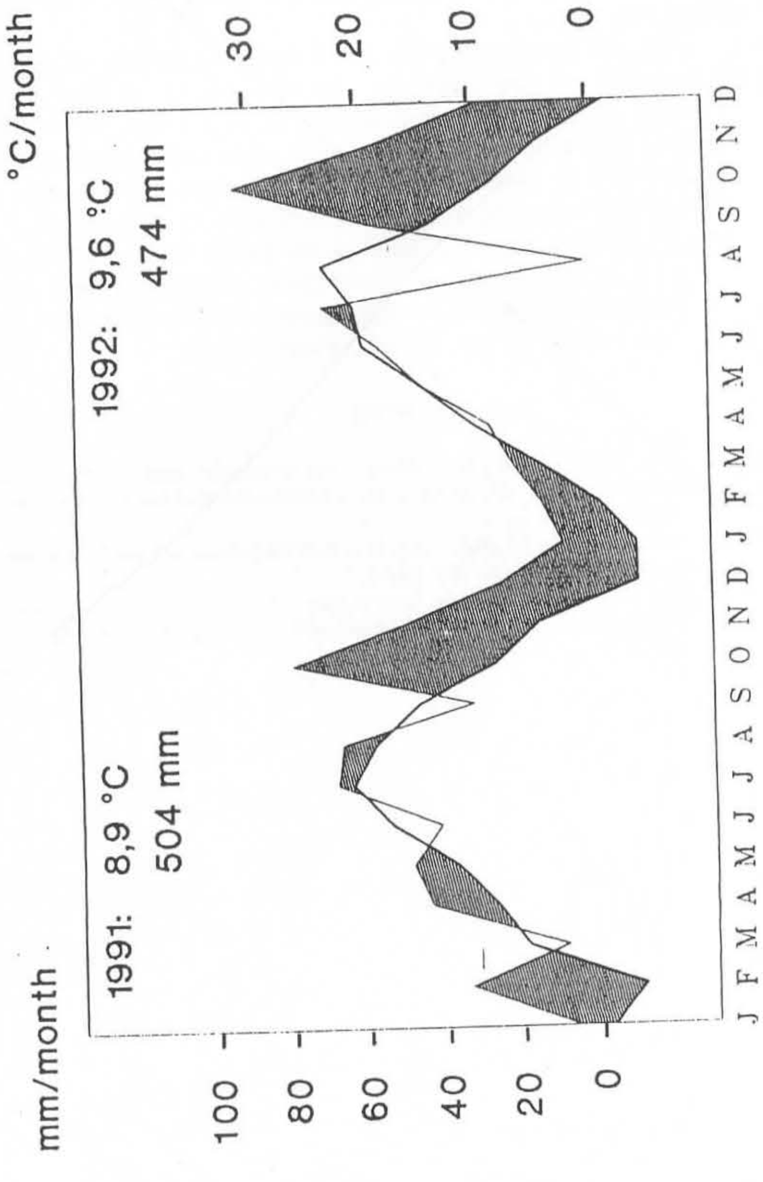
Our paper is focused on synecological comparison of collembolan communities of two localities with different soil type: albic luvisol and gleyic fluvisol. Both sites are characterized by the same climatic conditions and the same cropping system during most of the investigation time.

METHODS

The experimental sites are located in the East-Slovak Lowland in south-eastern part of Slovakia. The climate is continental with mean annual temperature of +9.0°C and annual precipitation of 540 - 600 mm. The monthly means range from -2.6°C for January to +19.1°C for July. Monthly temperature and precipitation data recorded during the investigation period in the area under study (Meteorological station in Milhostov) are given in Fig. 1.

Two adjacent sites of different soil type at Čičarovce were chosen for a synecological study of *Collembola*. The soil types under study were albic luvisol (AL) and gleyic fluvisol (GF) according to FAO classification system (NĚMEČEK, SMOLÍKOVÁ, KUTÍLEK 1990). The distance between the sites was ca 1,000 metres. Their topographic situation was different, difference in altitude being 4.5 m (AL - 104 m a.s.l., GF - 99.5 m a.s.l.). This caused differences in pedogenesis of these soils and their edaphic characteristics (Table 1). The management calendar of the sites was practically the same during the investigation period (Table 2), excluding the end of 1992 and May 1993.

The investigations were carried out at two-month intervals in 1991 - 1992, with one supplemental sampling in May 1993. Eight replicates were taken during one sampling, using a device 6 cm in diameter and 10 cm deep. Each soil core was divided in two subsamples: 0 - 5 cm and 5 - 10 cm, and extracted separately. Samples were taken between the rows of crop and 50 metres at least from the edge of the field, to avoid possible ecotonal effect. They were transported in plastic bags



1. Seasonal changes of air temperature and precipitation (Meteorological station Milhostov)

Table 1
Characteristics of research sites for top soil layer 0 - 10 cm (C_{ox} - organic C content, N_t - content of total N, P_t - content of total P, A - abundance, S - species richness, H' - diversity, J' - evenness)

	Albic Luvisol	Gleyic Fluvisol
Soil texture [%] (May 1993)		
< 0,001 mm	18,27	30,42
0,001 - 0,01 mm	15,71	40,66
0,01 - 0,05 mm	48,27	23,56
0,05 - 0,25 mm	17,04	5,13
0,25 - 2,0 mm	0,72	0,23
Soil moisture [%] (0 - 5 cm layer, 1991 - 1993)	15,5	26,2
Soil-chemical characteristics (May 1993)		
pH (H_2O)	7,21	6,08
C_{ox} [%]	1,11	2,12
N_t [%]	0,09	0,25
C/N	12,33	8,48
P_t [mg.kg^{-1}]	542,0	791,0
Synecological characteristics of *Collembola* (1991 - 1993)		
A [ind./m^2]	950	1410
S	51	41
H'	3,17	3,06
J'	0,80	0,84

and extracted in TULLGREN funnels during 10 days using 40 Watt light bulbs with temperature 20°C in the beginning and 40°C at the end of extraction.

The material of *Collembola* was fixed and preserved in 75% benzinalcohol. The individuals were mounted on slides using RUSEK's method (RUSEK 1975) and determined in phase-contrast microscope. For synecological comparison of the communities the following characteristics were used: abundance, species richness, dominance, frequency, SHANNON-WEAVER's diversity index and PIELOU's index of evenness.

The composition of collembolan fauna was analysed with multivariate data analysis techniques. First, the data were logarithmically transformed according to the formula: $\log(x+1)$ to reduce the importance of extreme

Table 2
Management calender

	Albic Luvisol	Gleyic Fluvisol
	1990	
Sept.:	Fertilization with	
	27,5 kg/ha N	33 kg/ha N
	12,5 kg/ha P	15 kg/ha P
	37,5 kg/ha K	36 kg/ha K
	Liming with calcium - 3500 kg/ha	
	Sowing of winter wheat	
	1991	
March:	Fertilization with 69 kg/ha N	
April:	Undersowing of clover Treatment with Basagran (bentazone 48%) - 2 l/ha Aminex (MCPA) - 2 l/ha	
July:	Harvest of winter wheat	
	1992	
	Clover standing growth	
10 Aug.		Ploughing Fertilization with 24 kg/ha N
16 Sept.		Sowing of winter wheat
	1993	
May:	Ploughing Fertilization with 60 kg/ha N Sowing of maize Treatment with Stomp (pendimethalin 33%) - 5 l/ha Zeazin (atrazine 40%) - 1.5 l/ha	April: Fertilization with 46 kg/ha N Treatment with Aminex (MCPA) - 2.5 l/ha Glean - 5 g/ha (chlorsulfuron 75%)

values. The collected data on the occurrence of species and their quantity in samples were clustered with CLUSTR, a programme of PC-ORD package (MCCUNE 1987). WARD's method was the basis for hierarchical grouping. The similarity matrix was calculated using Euclidean distance. Division of samples into clusters was carried out at the distance value 2.391. For ordering samples and species in three-dimensional space Detrended Correspondence Analysis (DCA) was applied. DCA is an eigenvector ordination technique of the CANOCO programme (BRAAK 1988).

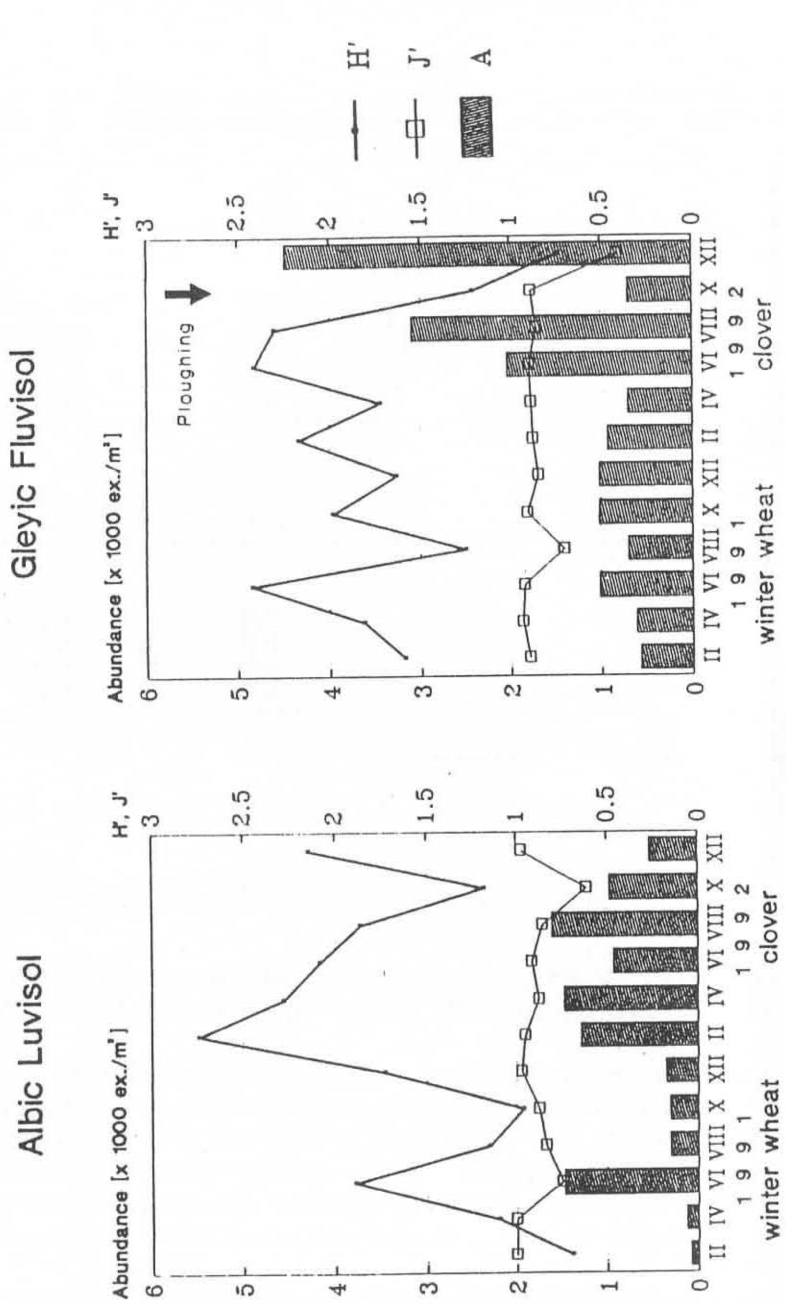
RESULTS

A considerable difference between sites in average abundance of their community from the whole experimental period is apparent (Table 1). A relatively high abundance of the community on fluvisol was observed in August and December 1992 (Fig. 2). The difference is practically the same taking into account the period with the same management practices (February 1991 - August 1992): luvisol - 800 ind./m² and fluvisol - 1200 ind./m². In most cases a higher abundance of the community was concentrated in 0 - 5 cm soil layer (Figs 3 and 4), except August and December 1992 on fluvisol, and May 1993. In general, a higher abundance in clover compared with winter wheat was recorded in spite of the less favourable climatic conditions in 1992 (Fig. 1). A deep ploughing of the site with fluvisol in October 1992 caused strong decrease of collembolan abundance in the upper as well as in the lower soil layer (Figs 2 and 4).

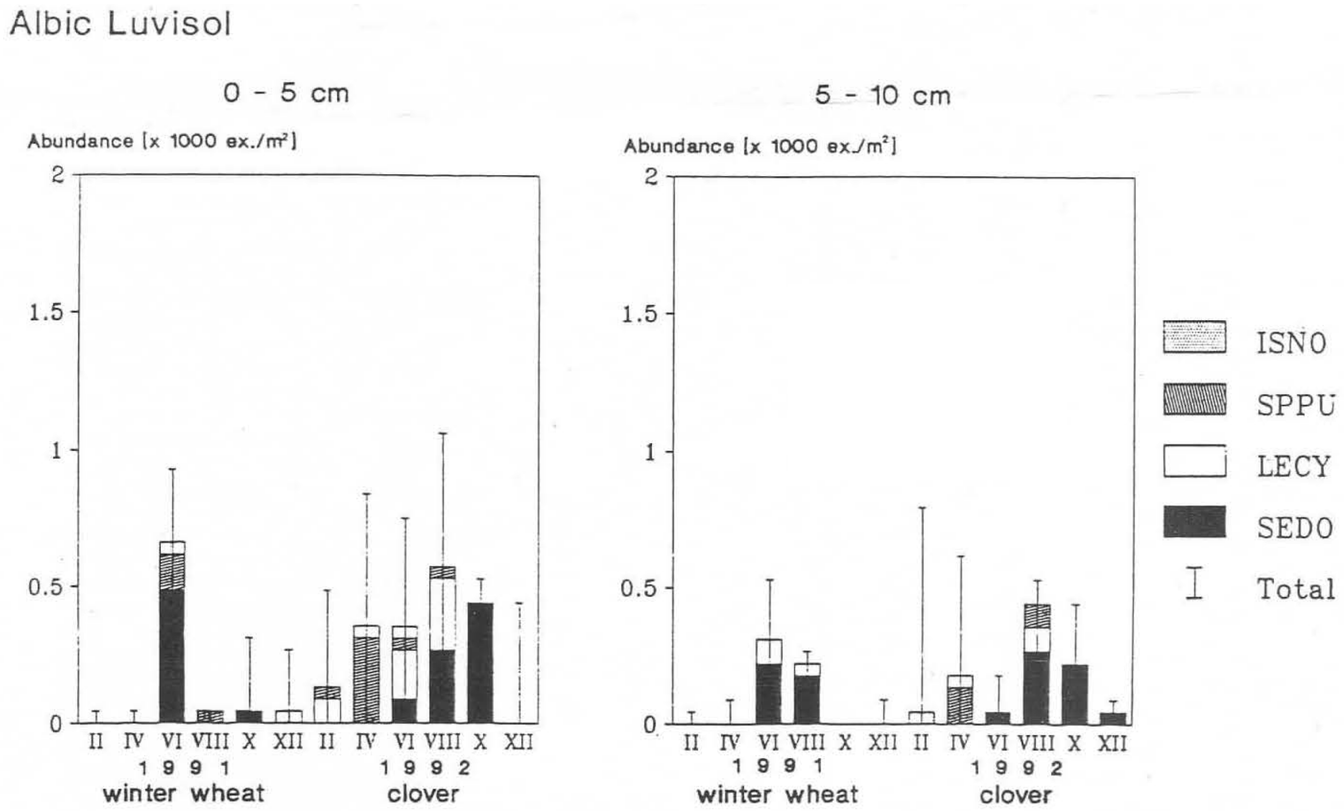
In total 63 species were found on both experimental sites, 51 on luvisol and 41 on fluvisol (Table 3). At the site with luvisol *Seira domestica*, *Sphaeridia pumilis* and *Lepidocyrtus cyaneus* had the highest average abundance and dominance, on fluvisol the most abundant and dominant species were *S. domestica* and *Xenylla boerneri*. In case of the latter species an extremely high population abundance in 5 - 10 cm soil layer was observed in December 1992 (Fig. 4). This was the reason for the maximum of community abundance at that period. A low frequency of *X. boerneri* on fluvisol (Table 3) reflects a high aggregation of its population. Its occurence was registered only in one of the eight sampling replicates in December 1992. On the other hand, there were several species that shared a high community abundance on fluvisol in August 1992, especially *S. domestica*, *Tetracanthella fjellbergi*, *Folsomia manolachei* and *S. pumilis*. They were concentrated in the deeper soil layer (Fig. 4).

Several species preferred a given site or soil type. For example, of the first twenty species five had more than twice higher frequency on luvisol than on fluvisol: *Protaphorura subarmata*, *Mesaphorura hylophila*, *M. macrochaeta*, *Entomobrya marginata* and *Onychiurus silvarius*. On the other hand, seven species which preferred fluvisol: *Protaphorura aurantiaca*, *Folsomia manolachei*, *F. quadrioculata*, *Ceratophysella succinea*, *Bourletiella hortensis*, *Pseudisotoma sensibilis* and *Orchesella multifasciata*.

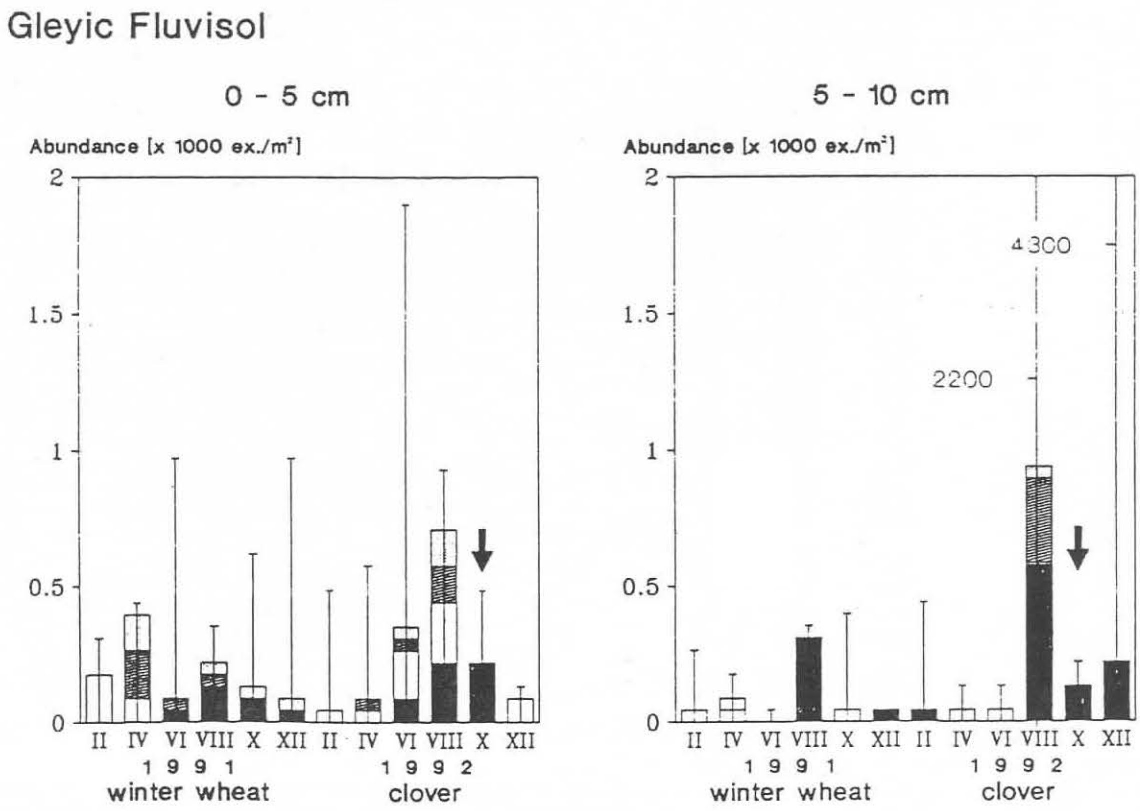
A higher diversity index at the site with luvisol compared with that with fluvisol partly reflects a higher species richness at that site. The evenness, on the other hand, was very similar on both sites.



2. Dynamics of collembolan abundance (A), diversity (H') and evenness (J') on experimental sites in 1991 - 1992



3. Share of frequent species in the dynamics of total community abundance in soil layers on site with albic luvisol in 1991 - 1992 (ISNO - *I. notabilis*, SPPU - *Sphaeridia pumilis*, LECY - *L. cyaneus*, SEDO - *S. domestica*, Total - total abundance of *Collembola*)

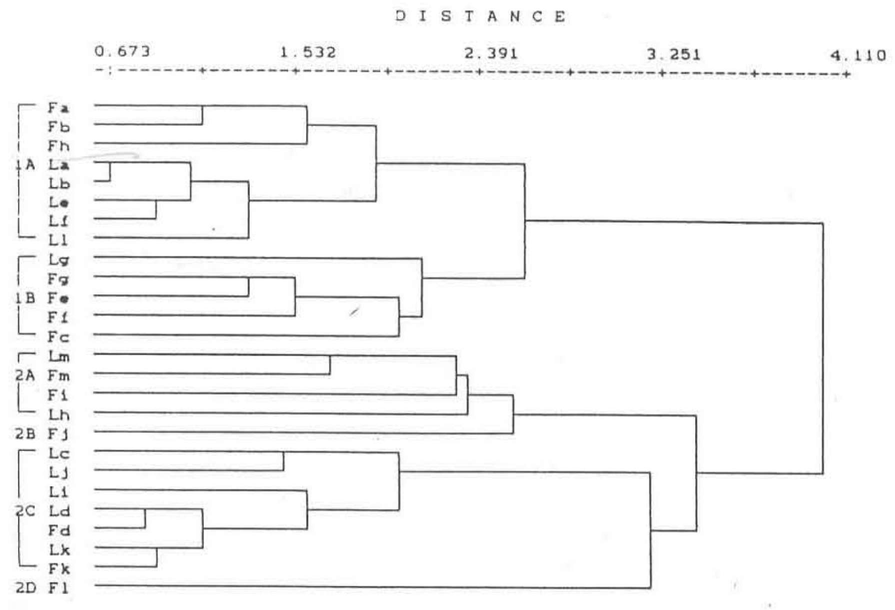


4. Share of frequent species in the dynamics of total community abundance in soil layers on site with gleyic fluvisol in 1991 - 1992 (Abbreviations of species see Fig. 3)

Table 3

Species abundance (A - ind./m²), dominance (D - %) and frequency (F - %) of *Collembola* on albic luvisol and gleyic fluvisol in 1991 - 1993

Species	Albic Luvisol			Gleyic Fluvisol		
	A	D	F	A	D	F
1	2	3	4	5	6	7
Seira domestica (NICOLET, 1842)	218	25.00	39.47	177	12.59	32.74
Xenylla boerneri AXELSON, 1905	-	-	-	283	20.10	0.88
Lepidocyrtus cyaneus TULLBERG, 1871	65	7.42	11.40	88	6.30	18.58
Sphaeridia pumilis (KRAUSBAUER, 1898)	78	8.98	13.16	61	4.36	9.73
Protaphorura aurantiaca (RIDLEY, 1880)	3	0.39	0.88	85	6.05	17.70
Isotoma notabilis SCHÄFFER, 1896	34	3.91	7.89	48	3.39	9.73
Folsomia manolachei BAGNALL, 1939	-	-	-	82	5.81	10.62
Ceratophysella succinea (GISIN, 1949)	20	2.34	5.26	58	4.12	11.50
Folsomia quadrioculata (TULLBERG, 1871)	3	0.39	0.88	75	5.33	14.16
Pseudosinella alba (PACKARD, 1873)	27	3.12	7.02	48	3.39	12.39
Bourletiella hortensis (FITCH, 1863)	14	1.56	3.51	44	3.15	7.96
Protaphorura subarmata (GISIN, 1957)	27	3.12	5.26	20	1.45	2.65
Lepidocyrtus lignorum (FABRICIUS, 1775)	17	1.95	4.39	27	1.94	6.19
Pseudisotoma sensibilis (TULLBERG, 1876)	7	0.78	1.75	37	2.66	7.96
Mesaphorura hylophila RUSEK, 1982	31	3.52	5.26	10	0.73	2.65
Entomobrya marginata (TULLBERG, 1871)	24	2.73	6.14	14	0.97	3.54
Tetracanthella fjellbergi DEHARVENG, 1987	7	0.78	1.75	31	2.18	2.65
Orchesella multifasciata STSCHERBAKOW, 1898	10	1.17	1.75	24	1.69	6.19
Mesaphorura macrochaeta RUSEK, 1976	24	2.73	3.51	7	0.48	1.77
Onychiurus silvarius GISIN, 1952	31	3.52	7.02	-	-	-
Sminthurus viridis (LINNÉ, 1758)	17	1.95	3.51	14	0.97	2.65
Willowsia nigromaculata (LUBBOCK, 1873)	10	1.17	2.63	14	0.97	3.54
Orchesella cincta (LINNÉ, 1758)	24	2.73	3.51	-	-	-
Isotoma viridis BOURLET, 1839	10	1.17	2.63	10	0.73	2.65
Mesaphorura krausbaueri BÖRNER, 1901	7	0.78	1.75	14	0.97	3.54
Sminthurinus elegans (FITCH, 1863)	3	0.39	0.88	17	1.21	1.77
Xenylla cf. greensladeae GAMA, 1974	-	-	-	20	1.45	2.65
Xenyllodes armatus AXELSON, 1903	7	0.78	1.75	14	0.97	3.54
Protaphorura armata (TULLBERG, 1869)	14	1.56	3.51	3	0.24	0.88
1	2	3	4	5	6	7
Ceratophysella armata (NICOLET, 1841)	-	-	-	17	1.21	1.77
Pseudanurophorus boerneri STACH, 1922	17	1.95	4.39	-	-	-
Ceratophysella engadinensis (GISIN, 1949)	14	1.56	3.51	-	-	-
Friesea truncata CASSAGNAU, 1958	3	0.39	0.88	10	0.73	2.65
Megalothorax minimus WILLEM, 1900	-	-	-	10	0.73	2.65
Isotomiella minor (SCHÄFFER, 1896)	7	0.78	1.75	3	0.24	0.88
Tomocerus minutus TULLBERG, 1876	10	1.17	1.75	-	-	-
Hymenaphorura carpatica STACH, 1953	7	0.78	0.88	-	-	-
Heteromurus nitidus (TEMPLETON, 1835)	3	0.39	0.88	3	0.24	0.88
Mesaphorura tenuisensillata RUSEK, 1974	3	0.39	0.88	3	0.24	0.88
Isotoma anglicana LUBBOCK, 1862	7	0.78	1.75	-	-	-
Pseudachorutes dubius KRAUSBAUER, 1898	-	-	-	7	0.48	0.88
Mesaphorura critica ELLIS, 1976	7	0.78	1.75	-	-	-
Protaphorura cancellata (GISIN, 1956)	-	-	-	7	0.48	1.77
Cryptopygus ponticus (STACH, 1947)	7	0.78	1.75	-	-	-
Caprainea marginata (SCHÖTT, 1893)	7	0.78	0.88	-	-	-
Brachystomella parvula (SCHÄFFER, 1896)	3	0.39	0.88	3	0.24	0.88
Folsomia kerni GISIN, 1948	7	0.78	1.75	-	-	-
Pseudosinella cf. pongei GAMA, 1979	3	0.39	0.88	-	-	-
Pseudosinella cf. fallax BÖRNER, 1903	3	0.39	0.88	-	-	-
Dicyrtomina ornata (NICOLET, 1842)	-	-	-	3	0.24	0.88
Sminthurides malmgreni (TULLBERG, 1876)	3	0.39	0.88	-	-	-
Friesea afurcata (DENIS, 1926)	3	0.39	0.88	-	-	-
Folsomia fimetaria (LINNÉ, 1758)	3	0.39	0.88	-	-	-
Sminthurinus aureus (LUBBOCK, 1862)	3	0.39	0.88	-	-	-
Onychiurus rectopapillatus STACH, 1933	3	0.39	0.88	-	-	-
Allacma fusca (LINNÉ, 1758)	3	0.39	0.88	-	-	-
Micranurida pygmaea BÖRNER, 1901	3	0.39	0.88	-	-	-
Isotoma germanica HÜTHER ET WINTER, 1961	-	-	-	3	0.24	0.88
Stenaphorura denisi BAGNALL, 1935	3	0.39	0.88	-	-	-
Willemia intermedia MILLS, 1934	-	-	-	3	0.24	0.88
Megalothorax incertus BÖRNER, 1903	-	-	-	3	0.24	0.88
Ceratophysella granulata STACH, 1949	-	-	-	3	0.24	0.88
Protaphorura hortensis (GISIN, 1949)	3	0.39	0.88	-	-	-

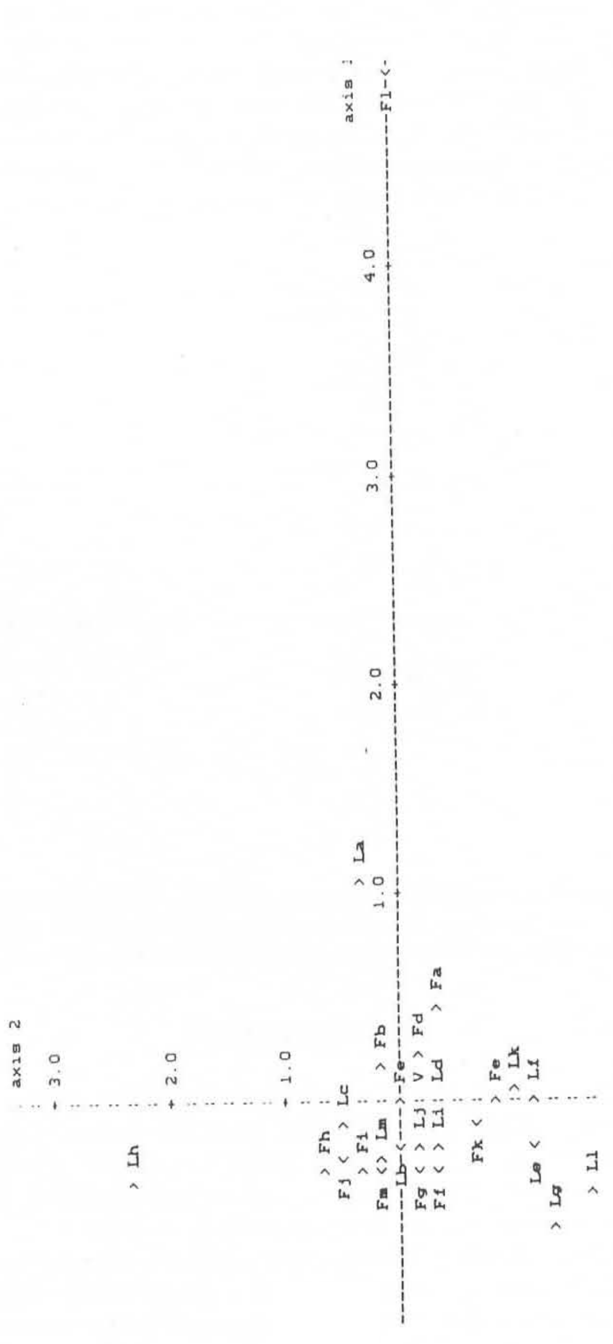


5. Cluster analysis of quantitative data on *Collembola* from the samples - Ward's method, Euclidean distance (Abbreviations of samples see Tab. 4)

According to their dynamics, values of both indices fluctuated to a high extent. A relatively rapid decrease in the indices was observed on fluvisol at the end of 1992 after a deep ploughing

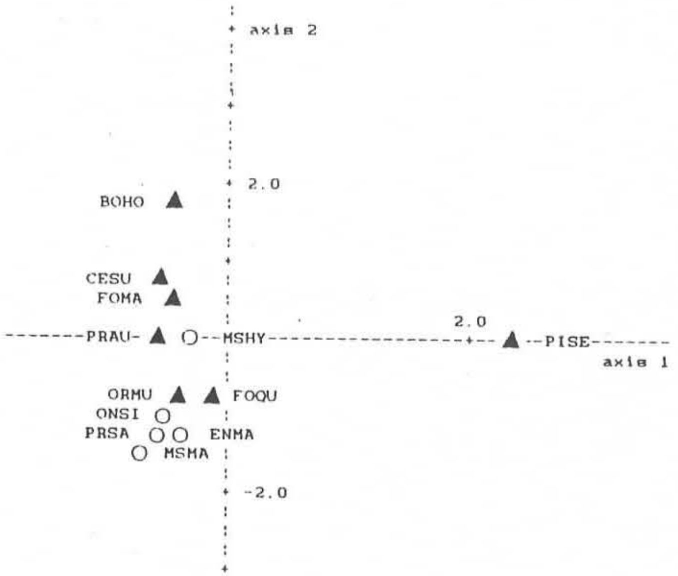
Grouping of samples in the cluster analysis dendrogram (Fig. 5) to a certain degree shows the effect of soil type. This is well visible in clusters 1B and 2C, where samples from the same soil type are mostly grouped. Cluster 1B is characterized by the occurrence of *Folsomia quadrioculata* and 2C by that of *S. domestica*. In cluster 1A samples from the same soil type were separated, whereas in those from fluvisol *L. cyaneus* and *Pseudisotoma sensibilis* and in those from luvisol *E. marginata* were the most abundant. Grouping samples--shows also the effect of sampling date. This effect is evident in clusters 1B, 2A and 2C, where samples of the same date are very similar, e.g. Ld - Fd, Lg - Fg, Lk - Fk and Lm - Fm.

The distribution of samples in ordination space (Fig. 6) is characterized by a strong separation of sample Fl with high aggregation of *X. boerneri*. Sample La with a high dominance of *P. sensibilis* is separated along the same axis 1. Sample Lh, in which *Folsomia kerni*, *Micranurida pygmaea*, *Pseudanurophorus boerneri* and *Stenaphorura denisi* are



6. Distribution of samples in ordination space - Detrended Correspondence Analysis (Abbreviations of samples see Tab. 4, eigenvalue of axis 1: 0.61, axis: 0.45)

the most abundant, is separated along axis 2. Seven samples create a branch on the level of negative values of axis 2. The distal five of them are from luvisol. This branch seems to reflect the influence of this soil type. Fig. 7 illustrates the distribution of species with preference to a given soil type. Species preferring luvisol are grouped in the same branch as the samples from luvisol (Fig. 6). Species from fluvisol, on the other hand, are dispersed mainly in the centre of ordination space.



7. Distribution of species preferring one of the soil types - Detrended Correspondance Analysis (Abbreviations of species see Tab. 4, eigenvalues of axis see Fig. 6, white circle - species preferring albic luvisol, black triangle - species preferring gleyic fluvisol

DISCUSSION

The absolute values of community abundance observed are rather low in comparison with literature data for arable soils (JAGERS OP AKKERHIUS et al. 1988, RÖSKE 1989, LAGERLÖF, ANDRÉN 1991). A drier continental climate and an underestimate due to the extraction method used may be the most important reasons.

On both sites the effect of crop is evident. The higher collembolan abundance in clover compared with winter wheat confirms the fact that legume fields have a higher abundance than cereals (ALEJNIKOVA,

Table 4

Abbreviations used in multifactorial analysis of data

Soil types	Sampling dates:	Species names:
L - albic luvisol	a - 27 II 1991	BOHO *Bourletiella hortensis*
F - gleyic fluvisol	b - 9 IV 1991	CESU *Ceratophysella succinea*
	c - 14 VI 1991	ENMA *Entomobrya marginata*
	d - 6 VIII 1991	FOMA *Folsomia manolachei*
	e - 8 X 1991	FOQU *Folsomia quadrioculata*
	f - 7 XII 1991	MSHY *Mesaphorura hylophila*
	g - 1 II 1992	MSMA *Mesaphorura macrochaeta*
	h - 6 IV 1992	ONSI *Onychiurus silvarius*
	i - 2 VI 1992	ORMU *Orchesella multifasciata*
	j - 4 VIII 1992	PISE *Pseudisotoma sensibilis*
	k - 5 X 1992	PRAU *Protaphorura aurantiaca*
	l - 7 XII 1992	PRSA *Protaphorura subarmata*
	m - 25 V 1993	

UTROBINA 1975, LAGERLÖF, ANDRÉN 1991). A negative effect of ploughing on *Collembola*, which was clear in the locality with fluvisol, is well known (EDWARDS, LOFTY 1875, EDWARDS 1984, etc).

The number of collembolan species recorded from one locality on arable soil is rather high. Many authors found 15 - 20 species (HEISLER 1989, RUSEK 1990, STERZYŃSKA 1990, LAGERLÖF, ANDRÉN 1991). This community parameter depends mainly on the sampling intensity and duration of investigation period. RÖSKE (1993) reported 40 collembolan species from an experimental field related to three-year study and 600 soil samples in total. It is apparent from Table 3 that a high proportion of species had dominance below 1%. The proportion of such species was 56.9% for luvisol and 53.7% for fluvisol. These species are not true field forms, mostly rare in arable soils. They may be considered as a potential of high biological activity of these soils, provided that environmental disturbances connected with intensive agriculture are eliminated (ploughing, use of heavy machinery, use of agrochemicals).

The texture plays an important role in the biological activity of soils. Clays are basic to formation of organo - mineral complexes. Soil aggregation is one of the most important factors controlling microbial activity and organic matter turnover (PAUL, CLARK 1989, LEE, PANKHURST 1992). The gleyic fluvisol in the experimental site is characterized by a high clay content in 0 - 10 cm layer, and also a higher nutrient and average soil moisture content compared with albic luvisol (Table 1). These differences connected with different pedogenenetical processes are probably the reason for different

synecological characteristics of *Collembola* in the soils under study, and for preferences of several species to a given soil type. However, interactions between pedological characteristics of soil types and collembolan communities in arable soils have required a broader-scale study. The present knowledge of this problem, mainly contributions of RÖSKE (1989), FROMM et al. (1993) and KOVÁČ (1994), shows difficulties in generalizing the results presented in this paper.

CONCLUSIONS

The study of collembolan communities on two different soil types, albic luvisol and gleyic fluvisol, in two adjacent sites with the same cropping system made it possible to estimate the effect of soil type on this fauna. Pedological characteristics were determined by differences in location of a given site in landscape relief, e.g. by differences in soil formation. The clay content of the soils was probably the main factor responsible for nutrient and soil moisture regime. Gleyic fluvisol with 71.0% clay had 2.12% organic matter and 1410 ind./m^2 of *Collembola* on average. On the other hand, albic fluvisol with 34.0% clay had 1.11% soil organic matter and an average collembolan abundance of 950 ind./m^2. The results support the hypothesis on the indirect effect of soil type on *Collembola* through its edaphic characteristics, namely soil texture, moisture and nutrient content. Further studies on sites with variable in edaphic parameters within the same soil type are required to estimate the effect of soil type on collembolan fauna as a component of decomposition food web in agroecosystems.

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